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INVESTIGATION OF ZONES OF MELT AND THERMAL EFFECT IN METALS UNDER THE EFFECT OF LASER EMISSION OF DIFFERENT DURATION

by

I. M. Gryaznov, A. A. Kovalev, et al.

EDITED TRANSLATION

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Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
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З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

INVESTIGATION OF ZONES OF MELT AND THERMAL EFFECT IN METALS UNDER THE EFFECT OF LASER EMISSION OF DIFFERENT DURATION

I.M. Gryaznov, A.A. Kovalev, L.I. Mirkin, P.I. Ulyakov (Moscow)

The characteristics of the structure of iron and steel after the action of laser radiation with the pulse duration of 0.5 to 12 ms. An increase in the pulse duration leads to a narrowing of the crater and to an increase in the quantity of the liquid phase remaining in the crater and dimensions of the zone of thermal effect. The laminarity of the flow of the liquid phase along walls of the crater and the absence of the substantial role of condensation from the gaseous phase are shown.

The information on the effect of the duration of radiation on characteristics of the melt zones and thermal effect with irradiation is of interest [1]. The iron-carbon and aluminum alloys were investigated.

The decrease in the time of irradiation (λ = 1.06 μm) was accomplished by the interruption of the pulse of complete duration of 1.7 ms by means of a high-speed shutter of the explosive type, synchronized with the time-regulated delay line. Here the time of the action of the radiation on the specimen was varied from 0.5 to 1.7 ms, and the front of the cutting off consisted of 200 μs. A pulse of duration of 12 ms was obtained by means of a special LC line connected to the discharge circuit of the pumping lamps.

The metallographic method is used for an evaluation of the dimensions of zones of the congealed melt and thermal effect.

Specimens of carbon steel 45 at a constant flow density ($3.5 \cdot 10^7$ W/cm^2) were subjected to the effect of a "shortened" pulse. The construction of panoramas of zones of the congealed metal and thermal effect with a magnification of 200 times and the measurement of areas of these zones in sections of the craters were made.

As is seen from Fig. 1, areas of the zones vary approximately identical, and here the dimension of the zones of thermal effect is larger, since the phase transition in the solid state requires insignificant expenditures of energy as compared with the heat of fusion, and, furthermore, part of the liquid is removed from the crater. The nonlinear growth in the area of the zones is explained both by the increase in the time of the heat contact of the hot products of vaporization with the growth in the duration and by an increase in the area of the internal surface of the crater.

Measurement of the microhardness showed a significant change in the hardness of the zone of the thermal effect (from 730 to 850), which for this steel consists of the transformed grains of the pearlite and pulverized ferrite, and also a certain increase in the hardness of the melt zone (Fig. 2).

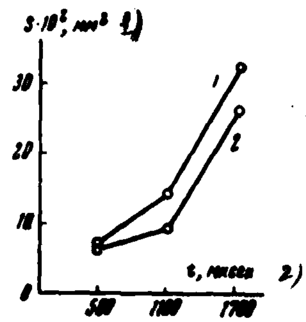

Fig. 1. Change in the area of zones of the congealed melt S and themal effect in sections of the craters in steel 45 with a different pulse duration: 1 - zone of thermal effect; 2 - zone of the melt. Key: 1) mm^2; 2) μs.

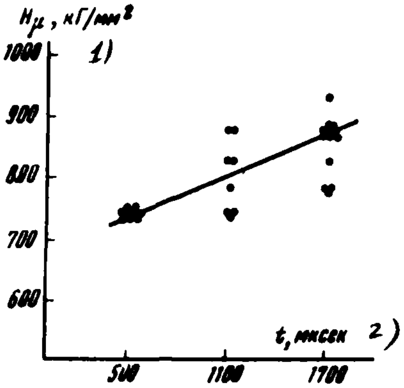

Fig. 2. Change in the hardness of the zone of thermal effect in steel 45 with a different pulse duration.

A further study of the effect of the time of irradiation was conducted on specimens of armco iron subjected to the action of OKG [laser] pulses with a duration of 12 and 2 ms at a flow density of $3 \cdot 10^6$ W/cm^2. For a comparison, conducted in the second series of experiments was the irradiation of specimens by pulses with a duration of 2 ms having the same total energy as that of pulses of 12 ms in the first series of experiments (table). An increase in the duration of irradiation with preservation of the constant density of flow of the energy leads to a considerable deepening of the crater without a change in its diameter. The control experiments on the irradiation of the iron by a pulse with the same energy but less duration show that an increase in the flow density of the energy by itself does not lead to a considerable increase in the depth of the crater. An equal change in the flow density of the energy and time of action leads to approximately identical changes in the volume of the zone of the melt. The change in the duration of irradiation has the most powerful effect on the volume of the zone of thermal effect.

It is interesting to make a comparison of the microhardness of the zones under different conditions of the irradiation. From the data given in the table, if follows that the microhardness of the melt zone almost does not change with a change in the conditions of irradiation, and the hardness of the zone of the thermal effect

with an increase in the duration is somewhat increased. This is connected, apparently, with the following causes. During the time of the standard laser pulse with a duration of 1-2 ms, it was not possible to produce not only the redistribution of the carbon in in the austenite between sections of the transformed pearlite and transformed ferrite, which was noted earlier [2], but also within the grains of the transformed pearlite between the plates of the transformed ferrite and cementite. As a result, with the cooling in this grain there appears martensite, which contains not 0.8% C but less. Let us note that the comparatively small content of carbon in the martensite in this case is confirmed by the data of x-ray analysis [3].

Table Charateristtic of craters and structures of the armco iron under different conditions of irradiation

(1) № п. п.	(2) Энергия, E, дж	(3) Площадь облучения, 10^{-3} см²	(4) Время облучения, 10^{-3} сек	(5) Глубина кратера, мм	(6) Диаметр кратера, мм	(7) Зона расплава		(8) Зона термического влияния	
						V, мм³	H_{50}	V, мм³	H_{50}
1	150	4	12	9.2	1.1	1.3	310	2.6	250
2	150	4	2	5.5	1.8	1.0	—	1.0	
3	25	4	2	5	1.1	0.35	300	0.35	220

Key: 1) No.; 2) Energy, E, J; 3) Area of irradiation, 10^{-3} cm^2; 4) Time of irradiation, 10^{-3} s; 5) Depth of crater, mm; 6) Diameter of crater, mm; 7) Melt zone; 8) Zone of thermal effect.

With an increase in the pulse duration up to 12 ms, the time of the heating in the zone of thermal effect is still sufficiently small so that the carbon would be able to be redistributed between the pearlite and ferrite,but within the grains of the pearlite after the transformation the carbon can be redistributed more uniformly, and the resulting martensite has a higher content of carbon and, consequently, higher hardness.

These discussions are applicable also for an explanation of results of the measurement of the hardness of steel after the action of the pulse, which was interrupted in the different stages.

With irradiation of specimens from aluminum (AV000) by laser

pulses with a duration of 12 ms, a large quantity of the congealed melt was observed in the crater. Estimates of the scattered energy give the magnitude of 15% of the total energy incident onto the specimen, whereas under these same conditions of action on the armco iron this figure consists of 3%. It is necessary to note that the depth of the crater in the aluminum is almost unchanged.

For the investigation of the structural changes in the different iron-carbon alloys under identical conditions of irradiation, the irradiation of the composite specimens at a flow density of 10^7 W/cm^2 was conducted. Specimens from different materials were pressed to each other by the polished surfaces, and the beam was directed along the interface; the focusing of the beam was carried out symmetrically with respect to both specimens with an accuracy of the order of 0.1 mm. After the irradiation, in each specimen along the edge a crater was located, and it corresponded in shape to a conical crater cut along it. The depth and shape of the craters in both halves of the specimen were identical, i.e., the change in the thermophysical properties of the material, due to the change in the composition, had practically no affect on the geometrical characteristics of the crater.

Interesting results have been obtained in the study of the surface of the crater for the steel-cast iron pair. In cast iron, apparently, due to its specific viscosity in the liquid state, observed on the surface of the appropriate half of the conical crater are drops of the congealed melt, and the surface of the crater in the low-carbon steel is smooth and shiny and does not contain drops, even though it has the structure of the congealed melt. From this observation it follows that the flow of liquid along the walls of the crater in its formation process is laminar, since mixings of the separate components are not observed. Furthermore, apparently, not playing a significant role is the condensation from the gaseous phase on the surface of the crater, since in this case the mixing of the materials would also be observed.

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